FCC ID: IDILJU-03

Prepared for:

Lojack Corporation
333 Elm Street
Declham, Massachusetts

By:

Professional Testing (EMI), Inc.
1601 FM 1460, Suite B
Round Rock, Texas 78664

Submitted to:

Federal Communications Commission
Equipment Approval Services
PO Box 358315
Pittsburgh, Pennsylvania 15251-3315

July 1999

FCC Application for Certification of an Intentional Radiator

Lojack Corporation
333 ELM STREET DEDHAM, MA 02026

Stolen Vehicle Recovery, Mobile Transceiver (Transmitter Portion)

Table of Contents

Appendices

Attachments

Certificate of Compliance

Applicant:	Lojack Corporation
Applicant's Address:	333 Elm Street Dedham, MA 02026
Model:	LJU-03
Serial Number:	0000004
Project Number:	00065-10
Test Dates:	08 July, 1999 and 14 July, 1999

I, Jeffrey A. Lenk, for Professional Testing (EMI), Inc., being familiar with the FCC rules and test procedures have reviewed the test setup, measurement data and this report. I believe them to be true and accurate. The **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** was tested and found to be in compliance with FCC Part 90 for Intentional Radiators.

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Jeffrey A. Lenk
President

1.0 Equipment Under Test (EUT) Description

The **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** Model **LJU-03** is a two-watt stolen vehicle recovery transceiver operating under the Commissions Part 90.19, Police Radio Service Rules, on a single shared channel. This system is commanded to transmit for a period of time, at about a 20% duty factor, which enables direction-finding equipment to locate a stolen vehicle. **Appendix A** is a technical description of the EUT and includes tune up procedures.

The **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** is intended for professional installation in normal over the road vehicles. It is not sold or available retail for consumer installation. This device meets the requirements of Part 90.20(e)(6). Specific test requirements include the following:

47 CFR 2.1046	RF Power Output
47 CFR 2.1047	Modulation Characteristics
47 CFR 2.1049	Occupied Bandwidth
47 CFR 2.1051	Spurious Emissions at Antenna Terminals
47 CFR 2.1053	Field Strength of Spurious Radiation
47 CFR 90.214	Transient Frequency Behavior
47CFR 2.1055	Frequency Stability
47 CFR 1.1310	Radiofrequency Radiation Exposure Limits

The **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** was tested in the transmit and receive modes of operation over the full range of vehicle voltages from 10 VDC through 16 VDC and from –30° C to 50° C with no out of specification conditions noted.

The system tested consisted of the following:

Manufacturer & Model	**Serial #**	**FCC ID #**	**Description**
Lojack Corporation, LJU-03	0000004	IDILJU-03	173.075 MHz Transceiver

Cables and Cords:

RG-223 Coaxial Cable (25 cm)

Support Equipment:

Laptop computer and interface box (Motorola supplied)

There are no options or sub-models available for this product. The measurements reported herein are representative of type testing on a worst case product. This transceiver was tested to verify its compliance with FCC Rules Parts 2, and 90, for Intentional Radiators. A separate verification report pursuant to Part 15, Subpart B has been prepared for the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** as a Digital Device and as a Receiver.

2.0 RF Output Power, §2.1046

Measurements were made on the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** to verify compliance with the maximum transmitter output power requirements of §90.20(e)(6).

2.1 Test Procedure

The antenna conductor of the EUT was terminated with a 6 dB attenuator and connected to the spectrum analyzer input. The EUT was powered from a variable DC power supply ranging from to volts to 16 Volts. Special control software was run on a laptop computer to command modulated and un-modulated transmissions. A Spectrum Analyzer with peak detection in a 120 kHz bandwidth was used to find the maximum RF output power. The spectrum analyzer calibration was verified against a reference HP 436A power meter to provide a 95% confidence Uc of 0.1 dB, 44 mW.

2.2 Test Results and Conclusion

The maximum RF output power obtainable was +32.75 dBm, 1.884 Watts. This RF output power is within the requested power shown on Form 731, page 2, item 8(b).
The Lojack Corporation protocol requires that the transmitter operate at a 20% duty factor, however for the measurements herein it was operated in a semi-continuous mode.

3.0 Modulation Characteristics, §2.1047

A schematic of the low pass filter as well as SPICE data describing the design evaluation is provided in Appendix B. Measurements were made on the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** to verify compliance with the requirements of §90.210(b).

3.1 Test Procedure

All measurements were performed in a controlled laboratory environment. The occupied bandwidth of the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** was measured using an Advantest R3265 Spectrum Analyzer with a transmit command signal provided to the EUT from a Motorola Lojack test control module. The EUT was terminated with an attenuator and the spectrum analyzer. Occupied bandwidth was measured at low and high battery voltages. The worst case occupied bandwidth is reported based on the emission width 26 dB below the peak emission level in a 1 kHz resolution bandwidth and is also shown against the Emission Mask of 90.210(b).

3.3 Test Results and Conclusion

Bandwidth testing results are located in **Appendix B** of this report. The widest (worst case) –26 dB bandwidths for the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** is listed below. The EUT meets the requirements of §90.210, emission mask (b).

Service Type	Reference Frequency	Occupied Bandwidth
13K2F2D	173.075 MHz	17.2 kHz

4.0 Spurious Emissions at Antenna Terminals §2.1051

Measurements were made on the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** to verify compliance with the maximum permissible value of §90.210(b). Particular care was exercised in evaluating the four harmonics falling in the restricted bands of §90.205.

4.1 Test Procedure

All measurements were performed in a controlled laboratory environment. The conducted spurious emissions of the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** were measured using an Advantest R3265 Spectrum Analyzer with a transmit command signal provided to the EUT from a Motorola Lojack test control module. The EUT was terminated with a 18 GHZ attenuator and the spectrum analyzer. The frequency range up to 1.8 GHz was investigated. Peak measurements are reported herein.

4.2 Test Results and Conclusion

The antenna conducted spurious and harmonic emissions for the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** is listed below. Worst case measurements are reported.

Transmitting:

Frequency Measured (MHz)	Recorded Level (dBm)	Limit §90.210(b) (dBm)	Margin (dB)
173.075	32.75	33.00	-0.25
346.15	-26.5	-13.3	-13.3
519.225	-35.7	-13.3	-22.5
692.300	-43.9	-13.3	-30.7

Receiving:

Frequency Measured (MHz)	Recorded Level (dBm)	Limit §15.111 (dBm)	Margin (dB)
101.130	-91.4	-57.0	-34.4
151.700	-67.0	-57.0	-10.0
303.400	-69.0	-57.0	-12.0
758.500	-74.0	-57.0	-17.0

5.0 Field Strength of Spurious Emissions §2.1053

Measurements were made on the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** to verify compliance with the maximum permissible radiated field strength of §90.210(b).

5.1 Test Procedure

For this two Watt transmitter, the harmonic and spurious emissions are limited to –46 dBc. The maximum level was determined by application of the formula of §90.210(b), which is,
At least 43 + 10 * Log (2 Watts) = -46 dBc

It was determined that for this FM transmitter, the modulated and unmodulated powers were the same so measurements were made with normal modulation. The normal duty factor of 20% was defeated in the control software to permit direct measurement on the OATS.

The EUT was placed on the 80 cm table on the turntable and powered from a supply placed below the tabletop. The power supply simulated nominal vehicle power, 13.5 VDC. Emissions found on frequencies from 50 MHz to 1.7 GHz were investigated and optimized by spinning the turntable over 360 degrees in azimuth and moving the antenna elevation from 1 to 4 meters to optimize the emissions

5.2 Test Results and Conclusion

The radiated spurious and harmonic emissions for the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** is listed below. Measurements were taken at 3.0 m with the transmitter terminated in a 50-Ohm dummy load, with normal output power and modulation. The measurement antenna was scanned from 1 to 4 m to maximize emissions. Worst case emission measurements are reported to show compliance with the Emission Mask of §90.210(b).

5.2 Field Strength of Spurious Emissions §2.1053, Cont'd.

Radiated Emission Data, 3.0m OATS, Horizontal

Freq. (MHz)	EUT Dir. (DEG)	Recorded Level (dBuV)	Antenna Factor (dB/m)	Cable Loss (dB)	Corrected Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)
57.692		18.2	17.2	0.89	36.3	84.0	47.7
346.150		42.3	14.0	2.39	58.7	84.0	25.31
519.225	**0**	**55.0**	**17.1**	**2.97**	**75.1**	**84.0**	**8.93**
692.300		35.0	20.9	3.51	59.4	84.0	24.59
1038.450		20.0	24.5	4.43	48.93	84.0	35.07
1211.525		27.0	24.7	4.88	56.58	84.0	27.42
1384.600		33.2	25.0	5.15	63.35	84.0	20.65
1557.675		36.1	25.4	5.53	67.03	84.0	16.97
1730.750		33.0	25.7	5.92	64.62	84.0	19.38

Average detection used above 1 GHz.

Radiated Emission Data, 3.0m OATS, Vertical

Freq. (MHz)	EUT Dir. (DEG)	Recorded Level (dBuV)	Antenna Factor (dB/m)	Cable Loss (dB)	Corrected Level (dBuV/m)	Limit (dBuV/m)	Margin (dB)
57.692		37.2	17.2	0.89	55.3	84.0	28.7
346.150		43.0	14.0	2.39	59.4	84.0	24.6
519.225	**0**	**48.8**	**17.1**	**2.97**	**68.9**	**84.0**	**15.1**
692.300		33.0	20.9	3.51	57.4	84.0	26.6
1038.450		20.0	24.5	4.43	48.93	84.0	35.1
1211.525		24.0	24.7	4.88	53.58	84.0	30.4
1384.600		24.0	25.0	5.15	54.15	84.0	29.9
1557.675		29.2	25.4	5.53	60.13	84.0	23.9
1730.750		28.5	25.7	5.92	60.12	84.0	23.9

Average used detection above 1 GHz.

6.0 Transient Frequency Behavior §90.214

Measurements were made on the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** to verify compliance with the maximum permissible transient frequency behavior of §90.214.

6.1 Test Procedure

All measurements were performed in a controlled laboratory environment. The frequency versus time behavior of the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** was measured using an Advantest R3265 Spectrum Analyzer with a random transmit keying command signal provided to the EUT from the Motorola Lojack control module. The EUT was terminated with an attenuator and the spectrum analyzer. The primary operating frequency was investigated. Peak frequency excursions, worst case, are reported herein.

6.2 Test Results

In every case the transmitter frequency settled to within ±25.0 kHz of the assigned channel within 5.0 ms and well within ±12.5 kHz in 20.0 ms.

7.0 Frequency Stability with Temperature §2.1055

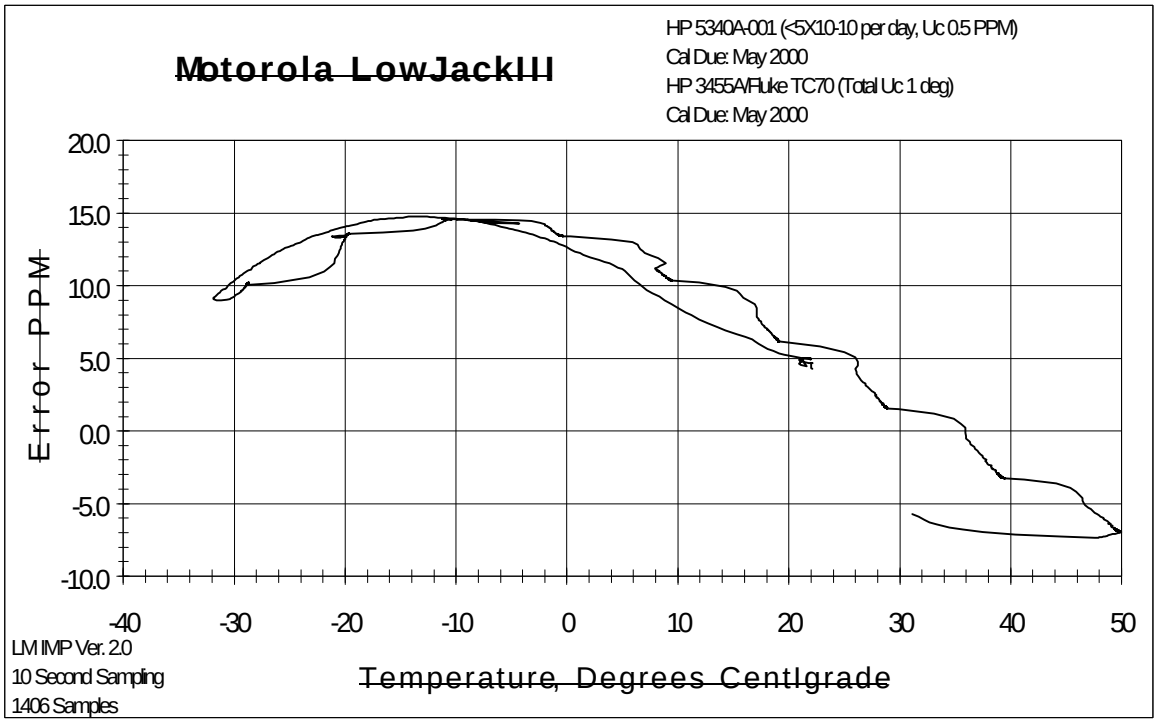
Measurements were made on the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** to verify compliance with the minimum frequency stability requirements of §90.213 for transmitters of two-Watts or less.

7.1 Test Procedure

The EUT was placed in an environmental test chamber and powered such that the frequency control element received normal voltage and the transmitter provided nominal RF output. A calibrated frequency counter and temperature probe were used with software written to log the frequency and temperature every 10 seconds. The chamber was programmed to cool from room temperature to –30 degrees C and then step in 10-degree increments, each step held for 20 minutes, to 50 degrees C. The logging software independently recorded temperature and transmitter frequency.

7.2 Test Results

Over the required test temperature range, the EUT maintained 22 PPM, which meets the requirements of §90.213 for transmitters with output powers of two Watts or less.



8.0 Radiofrequency Radiation Exposure Evaluation §1.1310

An evaluation was performed to provide data regarding the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** with respect to the Radiofrequency Radiation Exposure requirements of 47 CFR 1.1310.

8.1 Evaluation Procedure

The primary method of controlling radio frequency radiation exposure from the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** is the responsibility of the installer of the equipment. The device is to be professionally installed by personnel trained and familiar with installation and configuration of low power transmitting systems. The installer is responsible for antenna location. Final compliance with the Commissions RF an exposure regulation for this type of installation is the responsibility of the installer and is addressed under OET Bulletin 65.

8.2 Evaluation Results

The output power level for the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** is reported in the User's Manual as being 2 watts. In addition, the operating frequency for this device is reported as being 173.075 MHz. Based on this information, the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** could possibly produce an 11 V/m (0.032 mW/cm^2) field at 1 meter – if the antenna used could realize 3 dBi gain. This power density, 1/3 the MPE for uncontrolled environments, is unlikely to be attained. To obtain possible hazardous levels of RFR (0.1 mW/cm^2) a person would have to get within 50 cm of the radiator, a condition that is unlikely considering the covert antenna installation. The EUT meets the necessary requirements regarding possible RFR exposure.

9.0 Form 731 Information

The following information is provided for inclusion in the FCC Form 731 for the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver.**

9.1 Emission Designator

13K2F2D

9.2 Output Power

In the conducted power tests, the highest power attained was 32.75 dBm (2 watts). The tune up procedure specifies a goal of two watts.

Output Power: 2.0 Watts

9.3 Frequency Band of Operation

The **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** is only rated to be used in the shared police radio service on a specific channel. The only available transmitter frequency for the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** is:

Operating Frequency: 173.075 MHz

9.4 Grant Notes

The only exceptions or notes that would normally be listed for this device are:

10.0 Modifications

There were no modifications made to the **Lojack Corporation 173.075 MHz Vehicle Recovery Transceiver** to meet the current FCC requirements.

11.0 List of Test Equipment

A list of the test equipment utilized to perform the conducted and radiated emission measurements is given below. The date of calibration is given for each.

Device	Description	Date Last Calibrated	Calibration Due
Thermotron SM-3	Environmental. Test Chamber	10-05-98	Oct 1999
HP3456A	Digital Voltmeter	01-07-99	Jan 2000
HP 5340A	Frequency Counter	06-6-99	Jun 2000
FLUKE 80-T	Temperature Probe	1-99	Jan 2000
MITEQ ZKL	Preamplifier	1-99	Jan 2000
EMCO 3108	Biconical Antenna	8-98	Aug 1999
EMCO 3146	Log Periodic Antenna	12-98	Dec 1999
L/M 1-18-2	Double Ridged Horn Antenna	12-10-98	Dec 1999
Advantest R3265	Spectrum Analyzer	12-09-98	Dec 1999
HP 8481B-10	Attenuator	05-15-99	May 2000
MITEQ 0.1-20GHz	Preamplifier	1-99	Jan 2000

LoJack III

Theory of Operation

And

Tuning Procedure

Motorola AIEG

Revision: A

June 29, 1999

FORWARD

This document describes the theory of operation and the transmitter tuning procedure for the third generation LoJack Vehicle Locating Unit (VLU) transmitter. Please refer to Motorola Schematic 79D43701L01 for circuit and part references.

The LoJack III VLU (LJU3) is a VHF radio transceiver controlled by a remote network of computer activated transmitters. It is meant to be the tracked device in a vehicle location and recovery system. The VLU and associated antenna assembly are mounted in a secret location within the vehicle in a standby state until activated via a radio signal broadcast. Active state transmissions consist of periodic transmissions of coded data that can be tracked by a compatible tracking receiver.

TRANSMITTER

The LJU3 transmitter is a 2.0 Watt RF output, VHF FM device operating at 173.075 MHz. The transmitter is comprised of the following subsections: power supply, microprocessor controlled bias/modulation, baseband filter, crystal oscillator/modulator/tripler, 2nd frequency tripler, preamplifier, driver amplifier, power amplifier, transmit/receive switch, and low pass harmonic filter.

Power Supply

The LJU3 is designed to be power from a vehicle's 12 V power system. In the event that the vehicle power goes out of regulation, the LJU3 module contains an internal non-rechargeable 6 V lithium manganese battery cell. The unit will operate the transmitter from the primary power supply under normal operating conditions. Before powering the transmitter the microprocessor measures the primary power supply voltage. If the supply is out of range, the transmitter is powered from the back up battery.

The 12 V primary supply to the transmitter is regulated down to 8.2V to power the transmitter. When the back up battery is used the cell voltage (6 volts), combined with the loss in the switching and protection circuitry, limits the voltage.

A precision voltage reference is also provided to the transmitter to provide for increased oscillator frequency stability and to provide for controlled biasing of the preamplifier stage. This reference voltage is switched on by the microprocessor.

Microprocessor

The microprocessor is a Motorola MC68HCL11E9 microcontroller. It uses an external 8 MHz crystal and an internal 2 MHz bus. The microcontroller performs the following functions related to the transmitter: power switching, PA bias control, reference voltage switching, generation of the modulation signal, and carrier frequency tuning.

As detailed in the Power Supply section the micro determines the voltage at the primary power supply to determine if the transmitter should be operated from primary or back up power. The micro also uses a 6-bit discrete digital to analog circuit to provide a DC bias to the MOSFET

power amplifier device and controls a voltage reference circuit that is used in the transmitter section. Finally the micro also uses a discrete 8-bit digital to analog circuit to provide a sinusoidal signal to the crystal oscillator/modulator via the baseband filter. The sinusoidal signal is DC offset to control the center frequency of the transmitted signal.

Baseband Filter

The baseband filter is a passive two-pole low-pass filter. The filter smoothes the output of the 8-bit D/A to reduce the high frequency components in the sinusoidal MSK signal used to modulate the carrier frequency.

Crystal Oscillator/Modulator/Tripler

The transmitter crystal oscillator tripples the 19.23055MHz crystal frequency to 57.69165 MHz. The frequency is pulled using a varactor diode in series with the oscillator crystal. A buffer circuit isolates the crystal oscillator from the next tripler stage and a cap-coupled three-stage band-pass filter provides harmonic attenuation.

2nd Tripler

The 2nd Tripler stage tripples the 57.69165 MHz frequency to the173.075 MHz carrier frequency and provides power gain before the transmitter signal is fed to the preamplifier stage. The 2nd tripler also provides additional harmonic filtering using a three-stage cap-coupled band-pass filter.

Preamplifier

The output of the 2nd tripler is fed into the preamplifier stage. This stage uses the voltage provided by the voltage reference to bias a bipolar transistor into Class A. The stage amplifies the signal provided by the 2nd tripler and provides the higher amplitude signal to the driver stage of the transmitter. The preamplifier stage uses a fixed value 'T' matching circuit to match the output of the 2nd tripler to the input of the transistor and a 'shunt L series C' combination to match to the input impedance of the driver device.

Driver

The driver stage consists of a Class C biased bipolar device. The device uses feedback to insure stability and amplifies the signal delivered by the preamplifier stage for delivery to the power amplifier (PA) stage. The driver is matched to the PA using capacitive tapped coupling.

Power Amplifier

The power amplifier (PA) is a MOSFET device. It is biased from the microprocessor through a 6 bit digital to analog converter. The digital to analog circuit has bypass capacitance in the form of C3 and C75 to minimize any transference of RF between the micro and the PA and vice versa. The PA is matched to the transmitter switch via the first section of the low pass harmonic filtering.

Harmonic Filter

The harmonic filter in the transmitter consists of two sections. The first section consists of two 'series L, shunt C' circuits (L25, C109, L24, C107) that provides both low pass filtering and matching from the PA to the transmitter switch. After the transmitter switching diode a second section of filtering consists of a 'T' circuit (C114, L23, C117). This circuit (coupled to the antenna via C113) provides filtering for the transmitter and receiver and insures that the antenna is matched to the transmitter and receiver circuits.

Transmit/Receive Switch

The transmit/receive switch allows the use of a single antenna for both transmit and receive functions. PIN diodes D13 and D10 are unbiased in the receive mode. In this mode both diodes are of high impedance which isolates the transmitter from the antenna. When the transmitter is powered, both diodes are biased "on" via L18 and R123. This causes both diodes to look like low impedance circuits, D13 then connects the transmitter to the antenna.

TRANSMITTER TUNING

The LoJack III will be electronically tuned in a manufacturing test bay. The tuning procedure is as follows:

Center Frequency Tuning:

Establish two way serial communications to the LJIII unit. Command the unit to turn on the transmitter with no PA bias and no modulation. Measure the center frequency using a frequency counter with 1 Hz resolution. Move the modulation digital to analog value until the center frequency is as close to 173.075 MHz as step size allows (average step size will be approximately 170 Hz). The center frequency must be between within 173074135 and 173075865 Hz. Store the level in EEPROM. If center frequency can not be obtained that is within test limits fail unit.

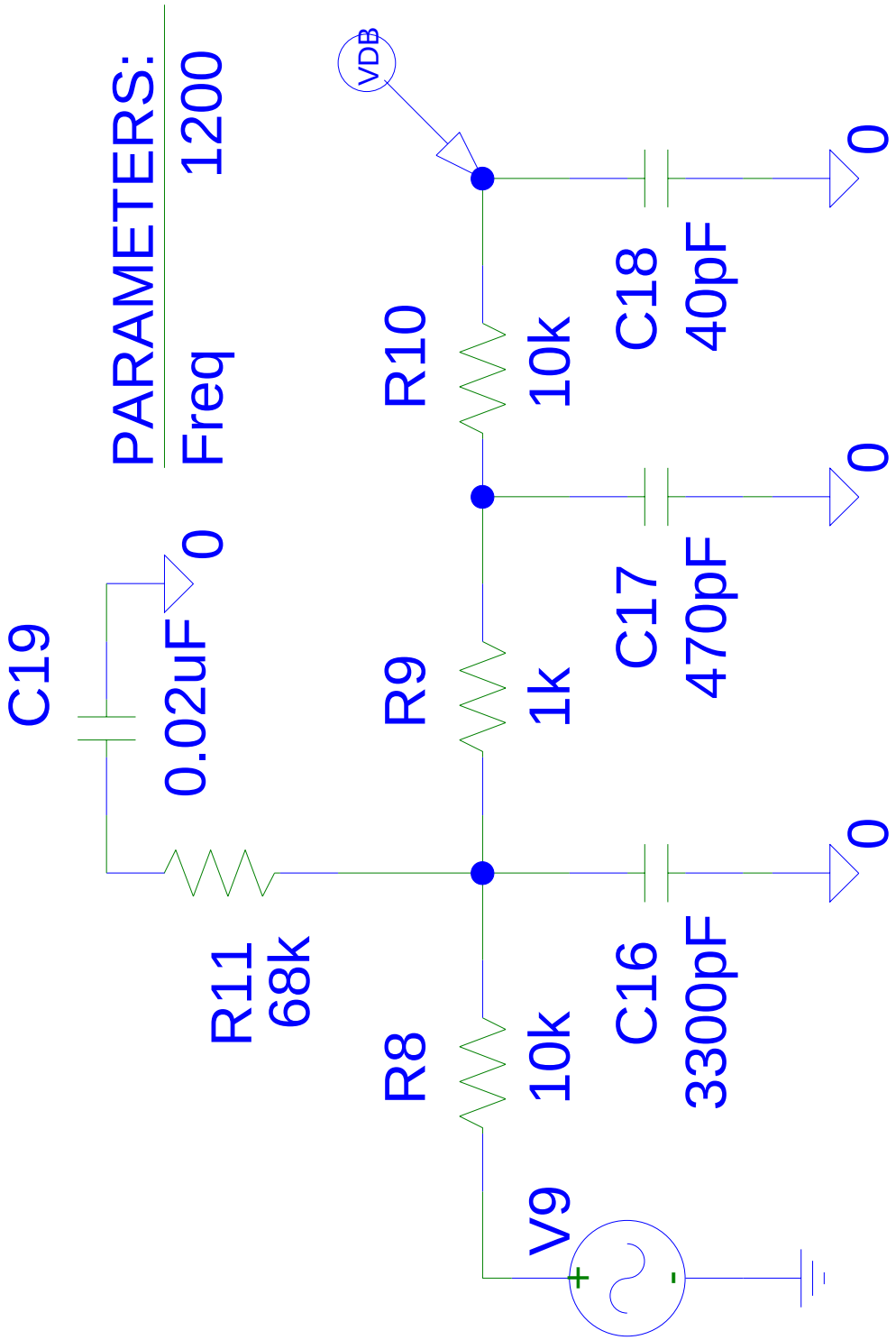
PA Bias:

Establish two way serial communications to the LJIII unit. Command the unit to turn on the transmitter with no PA bias and no reference voltage. This will bias the transmitter with no RF present. Measure the current into the unit. Increase the PA bias digital to analog value until the current level increases by 25 to 55 mA. The bias level that is the lowest in the range should be stored in EEPROM. If bias level between 25 to 55 mA is not obtained fail unit.

Turn on transmitter including PA bias and reference. Measure the power out of the transmitter. If power out is above 2.4 Watts or below spec adjust PA bias down or up respectively until power out is in spec. If power is not in spec within two digital to analog step sizes fail unit.

Appendix B

LPF and Occupied Bandwidth Test Data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C19
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R9
1k
R8
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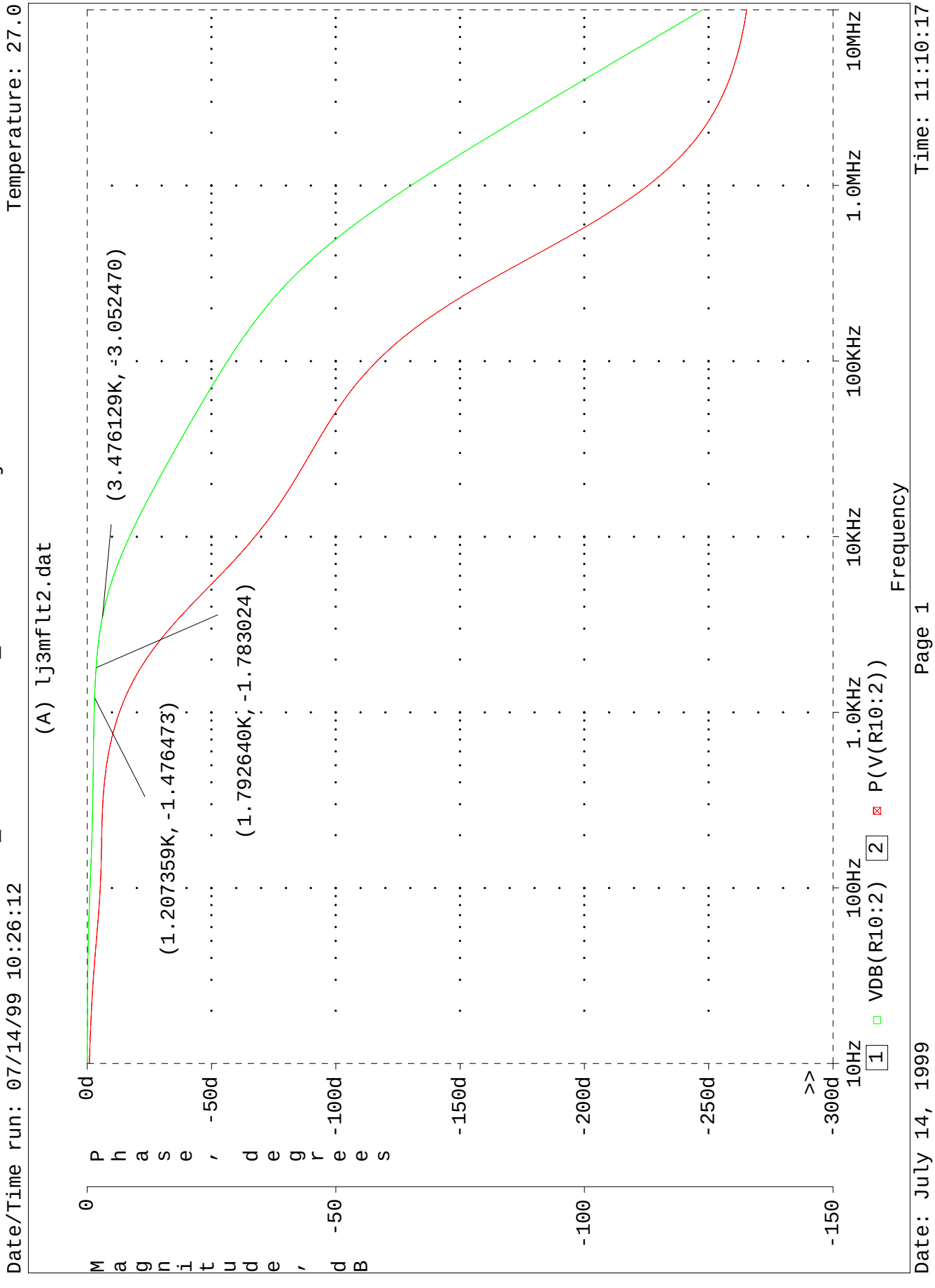
C16
3300pF
0
0
0
+
-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(1.207359K,-1.476473)
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Phase, degrees
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-150
0d
-50d
-100d
-150d
-200d
-250d
-300d
>>
10Hz
100Hz
1.0KHz
10KHz
100KHz
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Frequency
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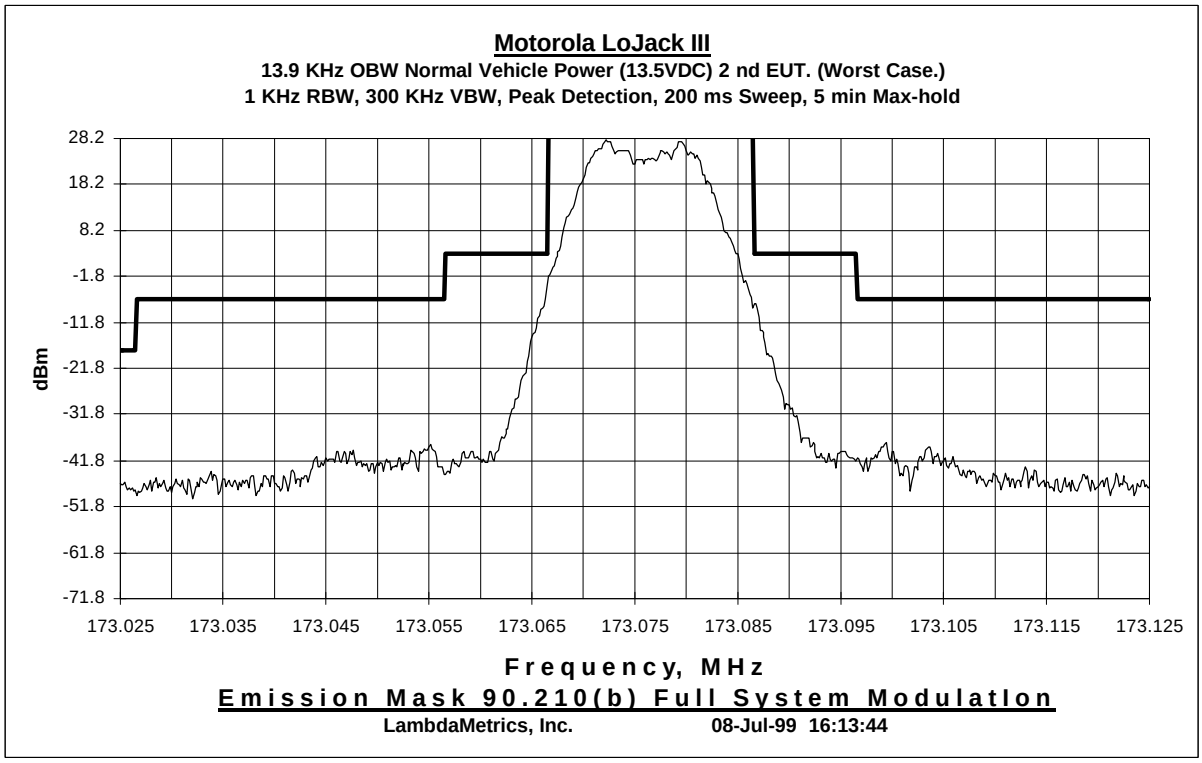
2 P(V(R10:2))
Page 1
Date: July 14, 1999
Time: 11:10:17

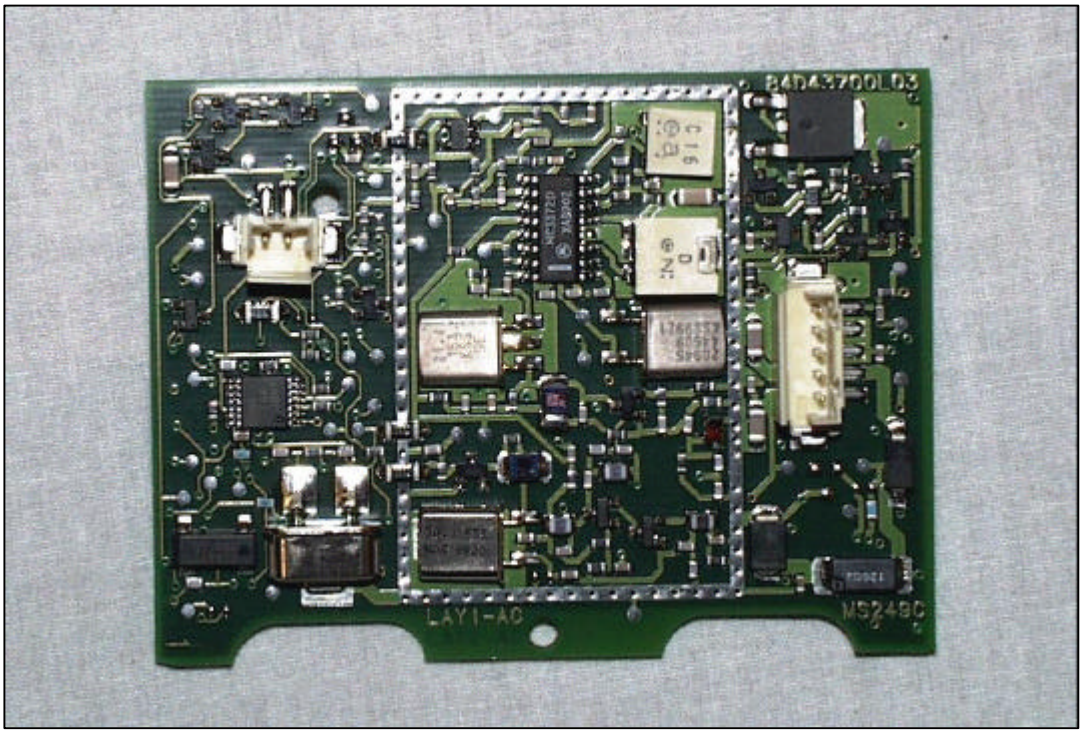


Emission Mask 90.110(b) applied to measured OBW data.

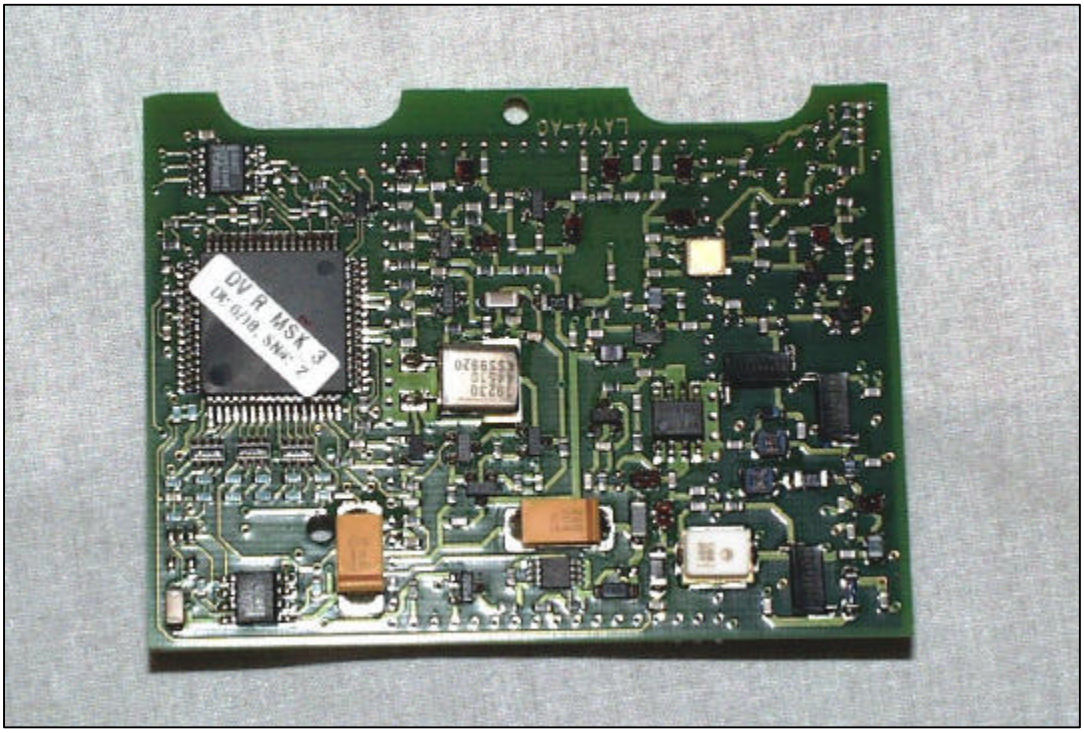
Appendix C Photographs

General View of EUT

FCC Label Placement



Printed Circuit Board, Top View



Printed Circuit Board, Top View